MENDELIAN INHERITANCE OF GENES AFFECTING VITAMIN-SYNTHESIZING ABILITY IN SACCHAROMYCES[1]

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Pedigrees describing both Mendelian and non-Mendelian inheritance of the ability to ferment carbohydrates in *Saccharomyces* have been reported by us (Lindegren and Lindegren, '47). Genes controlling the fermentation of galactose, maltose, or melibiose are transmitted in a regular Mendelian manner in some pedigrees, and in a non-Mendelian manner in others. Present indications are that this is due to the gene-to-gene transfer of some essential gene-component controlling fermentation. This phenomenon complicated the problem of genetical analysis of yeasts until regular Mendelian pedigrees were available.

The diagnosis of the fermentative ability of any selected culture is clear-cut, no difficulty being experienced in distinguishing a fermenter from a non-fermenter. In the present pedigree the fermentation of sugar is usually complete after 48 hours; the negatives do not ferment when held for three weeks. When regularly segregating pedigrees became available, the problem of genetical analysis of fermentative ability was capable of an uncomplicated solution.

Burkholder's medium (Lindegren and Raut, '47) is an excellent diagnostic medium for distinguishing pantothenate "synthesizers" from "nonsynthesizers," because a so-called nonsynthesizer grows rapidly in this meduim containing pantothenate, but requires weeks or months to produce growth in its absence. However, genes affecting vitamin synthesis are apparently transmitted in some pedigrees in a non-Mendelian way similar to that displayed by genes controlling fermentation. The first pedigree on the inheritance of "vitamin-synthesizing" ability in *Saccharomyces* (Lindegren, '45) failed not only to reveal regular Mendelian inheritance of this ability but also of genes controlling the fermentation of carbohydrates. In our selected inbred strains, the ability to ferment galactose and maltose is transmitted in a regular Mendelian manner, and the present paper shows that genes affecting the synthesis of paraminobenzoic acid, pantothenate, pyridoxine, and thiamin are transmitted with corresponding regularity. These genes are described as "affecting" rather than "controlling" the synthesis of vitamins, because we have not discovered any absolute deficiencies in yeasts. Lindegren and Raut have shown that a so-called nonsynthesizer of pantothenate eventually will grow in a medium without the addition of pantothenate, although some cultures do not begin growth until they have stood in the tubes for nearly a month.

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In genetical analysis, it is relatively unimportant whether absolute or partial deficiencies are dealt with; all that is required is a clear-cut differentiation of the haploid offspring of a hybrid into two different categories. This is easily effected in our present yeast pedigrees by using Burkholder's medium with and without added pantothenate. Genes affecting pantothenate and pyridoxine synthesis are easily diagnosed; the "nonsynthesizers" do not begin to grow until a week after planting while the "synthesizers" attain nearly full growth after 48 hours. The former may produce a turbidity reading of between 200 and 300, while the latter still show a reading of between 0 and 5. After the tubes have been held for two months it is difficult to distinguish them, but at 4 or 5 days the difference is pronounced. Cultures differing in genes which affect the synthesis of thiamin and paraminobenzoic acid show distinct differences at the end of 48 hours, but by the fourth day it is difficult to tell them apart. However, any clear-cut segregation of the progeny into two classes supplies the geneticist with an adequate gene "marker."

Table I describes 8 asci dissected from a hybrid heterozygous for mating type,

TABLE I

ANALYSIS OF ASCI FROM A HYBRID HETEROZYGOUS FOR MATING TYPE, FERMENTATION OF GALACTOSE AND MALTOSE, AND GENES AFFECTING THE SYNTHESIS OF PANTOTHENATE

(Ascospores from Hybrid 1426 × 1428 (a G ma pan × a g MA PAN))

Culture No.	Type	G	MA	PAN	Culture No.	Type	G	MA	PAN
	1					2			
2101	a	−	−	274	2105	a	+	−	5
2102	a	−	−	160	2106	a	−	+	190
2103	α	+	+	3	2107	α	−	+	2
2104	α	+	+	4	2108	α	+	−	254
	3					4			
2109	a	−	+	6	2113	α	−	−	3
2110	α	+	−	2	2114	α	−	+	210
2111	α	−	−	145+	2115	a	+	−	220
2112	a	+	+	274	2116	a	+	+	0
	5					6			
2121	a	−	+	0	2125	a			2
2122	α	+	−	200	2126	α	+	+	270
2123	α	+	−	5	2127	a	−	−	4
2124	a	−	+	345	2128	α	−	−	200
	7					8			
2147	α	+	+	290	2151	α		+	4
2148	a	−	+	137+	2152	α		+	250
2149	a		−	3	2153	a		−	140+
2150	α		−	8	2154	a		−	4

galactose fermentation, maltose fermentation, and a pair of genes affecting the ability of the organism to grow in Burkholder's medium without added pantothenate. The — and + signs under the columns G and MA indicate whether or not the organism produced gas in a medium containing galactose or maltose respectively. The figures under the column PAN show the turbidity reading registered in a Klett Photoelectric Colorimeter, after four days in a culture tube of Burkholder's medium without added pantothenate.

TABLE II

ANALYSIS OF ASCI FROM A HYBRID HETEROZYGOUS FOR MATING TYPE, FERMENTATION OF GALACTOSE AND MALTOSE, AND GENES AFFECTING THE SYNTHESIS OF PARAMINOBENZOIC ACID, THIAMIN AND PYRIDOXINE.

(Ascospores from Hybrid 2236 × 2090 (a G MA pab th py × α g ma PAB TH PY))

Culture No.	Type	G	MA	PAB	TH	PY
1						
2409	α	+	−	−	−	+
2410	a	−	−	+	+	−
2411	α	+	+	−	−	+
2412	a	−	+	+	+	−
5						
2423	α	−	−	−	−	−
2424	α	+	+	+	+	+
2425	a	+	−	−	−	+
2426	a	+	+	+	+	−
7						
2431	a	+	+	−	+	−
2432	a	+	−	+	+	+
2433	α	−	+	+	−	+
2434	α	−	−	−	−	−
9						
2439	α	+	−	−	−	−
2440	α	−	+	+	+	+
2441	a	−	+	−	+	+
2442	died					
11						
2447	a	−	−	+	−	−
2448	α	+	−	−	+	+
2449	a	−	+	+	+	−
2450	α	+	+	−	−	+

Culture No.	Type	G	MA	PAB	TH	PY
4						
2419	α	−	−	+	+	−
2420	a	−	+	+	−	−
2421	a	+	+	−	+	+
2422	α	+	−	−	−	+
6						
2427	a	+	−	+	+	−
2428	α	−	+	−	−	+
2429	α	−	−	−	+	−
2430	a	+	+	+	−	+
8						
2435	a	+	−	−	−	+
2436	a	−	+	+	+	−
2437	α	−	−	+	−	+
2438	α	+	+	−	+	−
10						
2443	a	+	+	+	−	−
2444	a	−	+	−	−	+
2445	α	+	−	+	+	−
2446	died					
12						
2451	a	−	−	+	−	+
2452	α	+	+	+	+	+
2453	α	+	+	−	+	−
2454	a	−	−	−	−	−

TABLE II (Continued)

Culture No.	Type	G	MA	PAB	TH	PY
13						
2455	α	+	−	−	−	+
2456	a	−	+	+	−	+
2457	α	−	+	+	+	−
2458	a	+	−	−	+	−
15						
2463	a	+	+	−	−	+
2464	α	−	+	+	+	−
2465	a	−	−	+	+	−
2466	α	+	−	−	−	+
17						
2471	α	+	−	−	+	−
2472	a	−	+	+	+	−
2473	α	+	−	+	−	+
19						
2477	a	+	+	+	+	−
2478	α	−	−	−	+	−
2479	a	+	+	+	−	+
2480	α	−	−	−	−	+
21						
2485	α	+	+	−	+	+
2486	a	−	+	+	−	+
2487	a	+	−	+	+	−
2488	α	−	−	−	−	−
23						
2493	α	+	−	−	+	−
2494	α	−	−	−	−	+
2495	a	+	+	+	+	−
2496	a	−	+	+	−	+
25						
2501	a	−	−	+	−	+
2502	a	−	−	+	+	−
2503	α	+	+	−	+	−
2504	α	+	+	−	−	+

Culture No.	Type	G	MA	PAB	TH	PY
14						
2459	α	+	+	−	−	−
2460	a	+	−	−	−	+
2461	α	−	−	+	+	+
2462	a	−	+	+	+	−
16						
2467	a	+	−	−	−	−
2468	α	−	−	+	+	+
2469	a	+	+	−	−	+
2470	α	−	+	+	+	−
18						
2474	α	−	+	−	−	−
2475	a	+	−	+	+	+
2476	a	+	+	−	−	+
20						
2481	a	+	−	−	+	−
2482	α	−	−	+	−	+
2483	α	−	+	−	+	−
2484	a	+	+	+	−	+
22						
2489	α	+	+	+	+	−
2490	a	−	−	−	+	+
2491	α	+	+	−	−	−
2492	a	+	−	+	−	+
24						
2497	α	+	+	−	+	−
2498	α	−	−	+	+	+
2499	a	−	−	−	−	−
2500	a	+	+	+	−	+
26						
2505	a	+	−	+	−	+
2506	α	−	−	−	+	−
2507	α	+	+	+	−	+
2508	a	−	+	−	+	−

Cultures 2111, 2148, and 2153 produced the recorded turbidity in the pantothenate-free medium after 48 hours and were discarded. They would doubtless have grown more, this being indicated by the + sign after the turbidity reading. Each ascus produced two cultures with a turbidity reading of less than 8 and two with more than 160 four days after inoculation. The genes controlling mating type, galactose fermentation, and maltose fermentation also segregated regularly in each of the eight asci.

Table II is a pedigree describing the cultures grown from the ascospores dissected from 24 asci. These asci are derived from a hybrid heterozygous for mating type, galactose fermentation, maltose fermentation, and genes affecting the synthesis of paraminobenzoic acid, thiamin, and pyridoxine. The + and — signs indicate whether or not the cultures ferment galactose or maltose, and whether they grow in Burkholder's vitamin-free medium. The readings on the paraminobenzoic- and thiamin-free media were made after 48 hours, while those in the pyridoxine-free medium were made after four days. Two of the cultures from each ascus produced heavy turbidity in the vitamin-free media while two produced practically no growth at the time diagnosis was made. The readings were all recorded numerically just as were the pantothenate readings shown in Table I, but for the purposes of clarity were converted into + and — signs in the table. The only exception to the expected Mendelian segregation of 2:2 in each ascus is found in asci Nos. 5 and 22 in which three fermenters of galactose were discovered, although the mating type, maltose fermentation, and vitamin characters segregated regularly.

Tests were made for linkage between all possible pairs of genes, and usually free assortment was indicated. In some cases linkage to each other or to different centromeres was suggested but the evidence was not sufficient to warrant definite conclusions. These data are presented to establish the fact that genes affecting vitamin synthesis may segregate in a regular Mendelian manner in selected inbred pedigrees.

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